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REQUIREMENTS FOR GRAPHIC TEACHING MACHINES.

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AN EXPERIMENT WAS REPORTED WHICH DEMONSTRATES THAT GRAPHICS ARE MORE EFFECTIVE THAN SYMBOLS IN ACQUIRING ALGEBRA CONCEPTS. THE SECOND PHASE OF THE STUDY DEMONSTRATED THAT GRAPHICS IN HIGH SCHOOL TEXTBOOKS WERE RELIABLY CLASSIFIED IN A MATRIX OF 480 FUNCTIONAL STIMULUS-RESPONSE CATEGORIES. SUGGESTIONS WERE MADE FOR EXTENDING THE CLASSIFICATION SYSTEM TO OTHER INSTRUCTIONAL MEDIA, INCLUDING MOTION PICTURES AND EDUCATIONAL TELEVISION. THE INFORMATION DYNAMICS CORPORATION DISCUSSED THE OPTICAL AND MECHANICAL REQUIREMENTS FOR GRAPHIC TEACHING MACHINES IN THE THIRD PHASE. PHASE THREE IS REPORTED IN ED 003 615. (RS)

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REQUIREMENTS FOR GRAPHIC TEACHING MACHINES

FINAL REPORT

Final Report
to the Commissioner of Education,
U.S. Office of Education
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under Grant No. 7-31-0570-161

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Abstract

Skinner's prototype teaching machine, from which the current practice of programmed instruction is derived, does not fully implement the tutorial process or Socratic dialogue. It concentrates on the ordering of verbal and symbolic behavior and only incidentally provides for graphic stimuli and responses.

To underline the importance of graphic stimuli and responses in learning, an experiment is reported which demonstrates that graphics are more effective than symbols in the acquisition of some concepts from Boolean algebra.

A second phase of the study demonstrates that graphics in high school textbooks can be reliably classified in a matrix of 480 functional stimulus-response categories. Suggestions are made for extending the classification system to other more dynamic instructional media, including motion pictures and ETV, approaching the fully integrated tutorial process.

In a third phase, Information Dynamics Corporation has discussed the optical and mechanical requirements for graphic teaching machines.

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Physical Requirements for Teaching Machines Using Graphic Displays	(Separately Bound)

FOREWORD

REQUIREMENTS FOR GRAPHIC TEACHING DEVICES

Question: "Here we have a square, have we not?"
Answer: "Yes, we do."

- Plato[1]

This famous dialogue between Socrates and the slave boy is often cited as a model of the tutorial process. To make the picture complete, Socrates should be shown drawing the square and subsequent geometric constructions in the sand with a stick.

Skinner's prototype teaching machine, and the discipline of programmed instruction it introduced, has been acclaimed as the "automation" of the Socratic dialogue (Galanter, 1961; Lumsdaine, 1960; Stolurow, 1962). Skinner's machine does implement certain important characteristics of the Socratic method: small steps, active response and prompt knowledge of results; but the machine, and consequently programmed instruction, concentrates on the verbal stimulus and response mode almost to the exclusion of the graphic. Skinner did not achieve the close integration of verbal and graphic stimuli and responses that Socrates accomplished by drawing in the sand as he talked with the slave boy.

As a step toward auto-instruction that would more closely approximate the optimum tutorial process, the authors proposed first to demonstrate the differential effects of symbolic, verbal and graphic stimulus and response modes on concept information. Although there

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[1] Plato. Laches, Protagorus, Meno and Euthydemus. Lamb, W. R. M. (ed. & trans.). London: Hiennemann, 1924.

had compared the effectiveness of a graphic display with that of a symbolic display, e.g., algebraic equation, when the concepts to be learned were formally equivalent. Experiments to test this hypothesis are reported in Part II.

A second purpose of the study was to define the requirements for teaching devices that would combine the characteristics of Skinner's prototype teaching machine with the closely integrated symbolic, verbal, and graphic stimulus and response characteristics of the tutorial process. The most efficient combination of these characteristics must be arrived at both rationally and experimentally. Accordingly, Part I describes a functional analysis and classification of graphic stimuli and responses in a conventional educational medium, high school textbooks. It demonstrates that instructional graphics can be reliably classified in S-R terms.

In addition to the analytical determination of requirements for graphic teaching devices, it was decided to probe the limits of the state of the engineering art in the photo-optical area. This was done (1) so that functional requirements could be set within the state of the art, or (2) so that research and development could be planned to extend the current state of the art as necessary. A survey by Information Dynamics Corporation, consulting graphics engineers, has been prepared as a separate Appendix to this report.

A. E. Hickey
Principal Investigator

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PART I

S-R ANALYSIS OF TEXTBOOK GRAPHICS

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Introduction

One purpose of the project was to define the physical characteristics of teaching devices suitable for the display of graphics in programmed learning. As a first step, it was evident that it would be necessary to know how graphics were currently used in the instructional process. It was thought that the use of graphics in existing media, i.e., book, film, lecture, etc., would provide a bench mark for the use of graphics in the projected teaching machine.

A search of educational literature revealed no existing taxonomic system summarizing the uses of graphics in educational media. There were technical and exhortative treatments of the topic (Campbell, 1953; Coons, 1957, 1960; Kinder, 1957), but none were found that were sufficiently analytic, systematic, or related to the behaviors of the display media or the audience. As a result, it was decided to make a systematic analysis of the educational uses of graphics: (1) to evaluate the feasibility of developing a general matrix of graphic educational stimuli, responses, and their relationships, and if feasible (2) to construct such a matrix to be used as reference in defining the requirements for graphic teaching machines.

Procedure

The medium chosen for study was high school textbooks. While this medium is not as rich in graphics as some others, it had the advantages of accessibility, physical circumscription, and broad subject

matter coverage. To insure that the content would be current and representative, the textbooks approved by the Boston School Committee served as the domain for analysis. The books on algebra, biology, and music were subject to complete analysis, while those on foreign languages, history, physical sciences were analysed partially to check the coverage and stability of the analysis. The books analysed are listed in Appendix B.

Operational definitions for graphic stimuli and responses were developed for use as analytic tools. A graphic stimulus was defined as any presentation material which departed from a narrative format or differed from the dominant format of the text. This was interpreted to include pictures, graphs, music, illustrative algebraic functions, logic diagrams, and tabular material. It did not include exposition in standard paragraph form, presentations which could be readily put into written form, i.e., where all meaning is conveyed by written presentation, or mathematical symbols in conventional linear format. A graphic response was defined as behavior required of a student that involved vocalizing, drawing or writing that departed from narrative form or conventional linear format. It was interpreted to include drawing pictures, graphs, and logic diagrams; vocalization in music, poetry, and foreign languages; and written tabular presentations. It did not include speech when the full meaning could be conveyed in written form, nor manipulation of symbols in conventional linear format.

The textbook analysis was based on the general model of media

content analysis (Berelson, 1954; Good & Scates, 1954). Using the operational stimulus and response definitions, the books were examined once to identify stimulus categories and once to identify response categories. The procedures followed independently for each subject were:

a. Examination for Stimuli. Using books as strata, a proportional stratified sample of book pages was drawn. The sample size was chosen to correspond to the average number of pages per book. Table I shows the sample sizes. A high school teacher was employed to examine each of the pages drawn, and to record on a card any graphics on the page. For each graphic stimulus so recorded, the examiner was directed to also examine adjacent material and record what the author of the text asked the student to do with the graphic stimulus, i.e., what response was demanded. No attempt was made to categorize non-graphic stimuli, but the response was categorized whether or not it involved graphic activity.

b. Examination for Responses. Since it was desired to record only specific unequivocal demands for responses, an arbitrary decision was made to sample only exercises at the end of each chapter. A percentage of the questions in these exercises was selected in a proportional stratified sample, where strata were chapter exercises. This percentage was chosen to make the number of responses sampled roughly correspond to the number of stimuli obtained in the preceding examination. For each response thus

Table 1

Textbook Samples by Subject

Subject	Books (N)	Stimulus (Pages)	Response (Exercises)
Algebra	7	503	294
Biology	5	562	274
Music	4	229	60
Total	16	1,294	628

recorded, the corresponding stimulus (the form of the exercise question) was also noted. Since the questions themselves were the sampling units, rather than book pages, it was possible to categorize each stimulus and response, regardless of whether graphic or non-graphic.

Once cards with stimuli and responses recorded on them had been obtained, the next step was to establish stimulus and response categories. This was done by giving each of two judges a small sample of the cards and requesting that they sort them into homogeneous groups according to the stimuli which they described and then the responses which they described. This sort was performed independently by the two judges. They subsequently compared the results of their sorts, collated their groupings, and agreed upon a title for each category. With tentative categories thus established, the judges independently sorted the entire sample. This sort verified the categories and served as a reliability check. The cards were then reexamined by the judges, disagreements were resolved by discussion, and the frequency of occurrence of stimulus-response combinations was determined.

Results and Conclusions

The sorts of materials abstracted from the textbooks on the subject matters included in the full analysis resulted in a set of 30 stimulus categories, a set of 16 response categories and, in combination, a matrix of 480 mutually exclusive and exhaustive Stimulus-Response categories. Inter-judge agreement for the stimulus categories

was 96% and for responses it was 93%. No agreement figure could be computed for the S-R matrix because it was formed after disagreements among the judges had been resolved.

The final 30 stimulus categories are listed below with their definitions. The proportional distribution of stimuli over the categories by textbook subjects is shown in Table 2.

Stimulus Categories

1. Arrows used to direct attention (a. black and white, b. color).

   Example: Red arrows are superimposed on the solution of an equation requiring division of a polynomial by a monomial. They call attention to the dividend and the quotient that have the same number of terms.

2. Line drawings, diagrams, and sketches (a. black and white, b. color).

   Example: A line drawing of a desk calculating machine with grey and red shading is presented as an example of one of a variety of computer types discussed in the text.

3. Photographs (a. black and white, b. color, c. with enlarged detail).

   Example: A photograph of a baseball diamond used to illustrate a discussion of probability.

4. Drawings and photographs superimposed or combined.

   Example: Photograph of engineers examining a mock-up aircraft with drawings of slide rule and drafting instruments forming a background.

5. Sequences (a. photographs, b. line drawings).

   Example: Sequence of photographs showing pre-natal development.

6. Color used to emphasize a word or number.

   Example: If $x = 0$, then $2x^2 - 5x + 4 = 4$ where "if" and "then" are printed in red.

7. Lines used to illustrate operations to be performed (a. black and white, b. color).

   Example: In solving a probability problem, where factorials are represented in both a numerator and denominator, red lines are used to cross out numbers to illustrate the cancellations which may be performed.

8. Box or background used for emphasis (a. black and white, b. color).

   Example: Rules for solving an incomplete quadratic equation set off in a red box.

9. Graphs (a. black and white, b. color).

   Example: Demonstration of graphic solution of a quadratic with the parabola in black and the coordinate system printed in red.

10. Geometric figures (a. black and white, b. color).

    Example: A rectangle printed in black with the diagonal printed in red as an aid in solving a problem where the diagonal and one side are given and the other side is to be found.

11. Tables (a. black and white, b. color). (Determinants are also included in this category because of their similar structure.)

    Example: For a given value of x, the corresponding value of y is presented in a table. The table is framed in red, with the values printed in black.

12. Questions or problems with supplementary graphic materials.

    Example: Diagram of a triangle with sides labeled and instructions to find the tangent of an indicated angle.

13. Verbally stated problems.

    Example: Write the formula for the sum of n terms of a geometric progression.

14. Numeric problems.

    Example: Given an equation, prove it for given values.

15. Combined verbal and numeric problems.

    Example: A man has twice as many dimes as he has pennies, and he has fewer nickels than dimes. If he has $2.64 in all, how many coins of each kind does he have?

16. Verbal questions.

    Example: What is meant by the term "polynomial?"

17. Numeric questions.

    Example: $(ab^3/a^2 - ab)\ (a - b/ab)$

18. Combined verbal and numeric questions.

    Example: What is the y-intercept of $y = 2x - 10$?

19. Numeric questions with verbal instructions.

    Example: Remove symbols of grouping and combine like terms: $10 - (a - 1)$

It can be seen in Table 2 that the distributions of graphic stimuli differ by subjects. For example, a large proportion of algebra stimuli are numeric; large proportions of those in biology are photographs, line drawings and verbal; and those in music are line drawings and verbal. The profile differences (Seigel, 1956) among the subjects are significant ($p < .01$). Because they did not provide new categories of stimuli, the subjects that were examined in addition to the three in the table were not analysed to the extent that they provided profile data.

The 16 response categories shown below with their definitions are the final set. The proportional allocation of responses over these categories for each subject is shown in Table 3.

Table 2

Stimulus Distribution by Subject

Key	Stimulus	Per Cent of Total Stimuli		
		Algebra	Biology	Music
1	Arrows to direct attention			
	a. black & white	01.0	00.0	00.0
	b. color	00.4	00.0	00.0
2	Line drawings			
	a. black & white	01.0	14.2	00.0
	b. color	00.6	04.7	81.1
3	Photographs			
	a. black & white	01.0	01.2	00.0
	b. color	00.0	22.2	04.7
	c. enlarged detail	00.0	02.3	00.0
4	Combined drawing & photographs			
	a. black & white	00.4	00.2	00.0
	b. color	00.0	00.5	00.0
5	Sequences			
	a. photographs	00.0	01.4	00.0
	b. line drawings	00.0	02.4	00.0
6	Color used as emphasis	00.4	00.2	00.0
7	Lines to show operations			
	a. black & white	02.0	00.0	00.0
	b. color	01.0	00.0	00.0
8	Box or background emphasis			
	a. black & white	03.0	03.5	00.0
	b. color	00.6	00.0	00.0
9	Graphs			
	a. black & white	07.0	00.0	00.0
	b. color	04.0	00.2	00.0
10	Geometric figures			
	a. black & white	04.0	00.0	00.0
	b. color	03.0	00.0	00.0

11	Tables			
	a. black & white	03.0	03.0	00.0
	b. color	03.0	00.5	00.7
12	Question or problem, supplementary graphic	01.0	00.7	00.0
13	Verbal problems	03.0	02.6	00.0
14	Numeric problems	01.0	00.0	00.0
15	Verbal-numeric problems	08.0	00.0	00.0
16	Verbal questions	03.0	40.5	13.5
17	Numeric questions	16.0	00.0	00.0
18	Verbal-numeric questions	18.0	00.0	00.0
19	Numeric questions, verbal instructions	11.0	00.0	00.0
	Total	100.0	100.1	100.0
	N	474	576	444

Response Categories

1. **Construct a table.**

   Example: Given an equation, in x and y, prepare a table showing y values for given values of x.

2. **Draw a diagram.**

   Example: Draw the appropriate figures for showing that the square of a tangent from a point to a circle is equal to the product of a secant from the point and the external segment of the secant.

3. **Draw a graph.**

   Example: Graph the equation $y = x^2 + 2x + 1$

4. **Use apparatus.**

   Example: Prepare mounting of a moth using required tools and materials.

5. **Vocalize.**

   Example: Produce song from score and lyrics.

6. **Follow demonstration of a method.**

   Example: Given an illustration of synthetic division, observe the steps so that the operations could be performed if required.

7. **Associate graphic and numeric stimuli.**

   Example: Given an equation and its graphic representation examine the two in order to be able to recognize the graph as "belonging to" the equation.

8. **Associate graphic and verbal stimuli.**

   Example: Given a graph of a line with points scattered about it, associate this with a verbal explanation of a least squares fit.

9. Attend to an emphasized objective.

   Example: Make use of contextual cues to abstract the important elements from a page, section, etc.

10. Take interest in a text objective.

    Example: Given an illustration of a space ship, exhibit increased motivation for working the mathematical problems adjacent to it.

11. Solve a problem numerically.

    Example: If y varies inversely as x, and y = 50 when x = 10, what is the value of y when x = 20?

12. Perform numeric operations.

    Example: Perform operations like divide, factor, take square root, etc.

13. Solve an equation.

    Example: Given an equation, solve for any desired values.

14. Perform derivation or proof.

    Example: Prove the theorem that in any proportion the product of the means is equal to the product of the extremes.

15. Answer verbally.

    Example: Answer in words the question, "What is an anti-logarithm?"

16. Insufficient information to establish a category. Those stimulus categories where the response proved too nebulous for categorization.

Table 3 shows that the distributions of responses differ by subjects. The most common responses in algebra were association of graphics with verbal stimuli and numeric operations. In biology, the most common responses were association of graphic with verbal stimuli and verbal answers. Music required a vocal response most often. Profile comparisons (Siegel, 1956) revealed significant differences between the profiles ($p < .01$). Again the other subjects could not be subjected to profile analysis.

Table 3

Response Distribution by Subject

Key	Response	Per Cent of Total Responses		
		Algebra	Biology	Music
1	Construct table	01.0	00.9	00.0
2	Draw diagram	02.0	00.0	00.0
3	Draw graph	04.0	00.0	00.0
4	Use apparatus	00.0	00.7	00.0
5	Vocalize	00.0	00.0	75.0
6	Follow demonstrations	08.0	01.4	00.2
7	Associate graphic & numeric stimuli	04.0	00.0	00.0
8	Associate graphic & verbal stimuli	18.0	49.1	05.2
9	Attend to emphasized objective	04.0	03.8	00.0
10	Take interest in text objective	02.0	01.2	06.1
11	Solve problem numerically	10.0	00.0	00.0
12	Perform numeric operations	31.0	00.0	00.0
13	Solve equation	07.0	00.0	00.0
14	Perform derivation or proof	03.0	00.0	00.0
15	Answer verbally	02.0	42.5	13.3
16	Insufficient information	04.0	00.3	00.3
	Total	100.0	99.9	100.0
	N	474	576	444

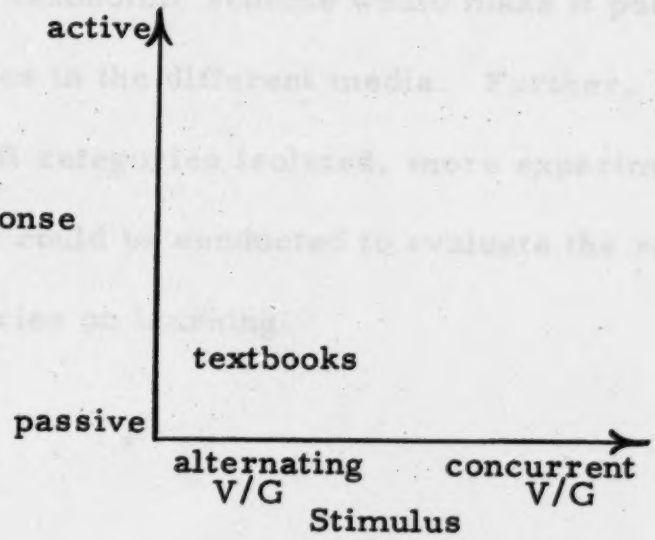
PRECEDING PAGE MISSING

The stimulus and response categories were used as orthogonal dimensions in forming an S-R matrix. Each cell of the matrix represents the intersection of a particular stimulus category and a particular response category. Therefore, each cell is an S-R combination. Figure 1 shows the matrix, and it includes within a cell the percentage of the S-R combinations in that cell for the combined algebra, biology, and music data. (Appendix A contains the S-R combinations for each subject.) Note the high percentage of combinations of stimulus categories 2, 3, 9, and 10 with the response category 8. In each case, the combination includes a graphic stimulus that is used as an ancillary illustration to a verbal presentation. Excluding line drawing, graphic responses to either graphic, verbal, or numeric stimuli did not reach one per cent, and in all, graphic responses occurred in only three per cent of the combinations. S-R combination 2a→5, line drawing and vocalizing, was contributed entirely by music. It is the only strong graphic S-R combination and is peculiar to the nature of music. In general, verbal and numeric stimuli required verbal and numeric responses, while graphic stimuli required associational or attitudinal responses. With the exception of music, it is concluded that graphics were used in the sample textbooks not as primary communications, but as only secondary elaborations of verbal and numeric stimuli and responses.

Discussion

The content analysis method applied in this study systematically reduced a complex and chaotic domain to a manageable set of meaningful categories. It resulted in objective information where casual observation and opinion had previously reigned, providing a basis for rational

judgments about the graphic content of textbooks. What originally appeared to be a rich and varied interaction of graphic, verbal and symbolic-numeric modes for instruction has been demonstrated to be a limited, stereotyped condition wherein graphics are in fact used only intermittently as supplements to already complete verbal or symbolic-numeric presentations. In a graphics-use space with stimulus and response vectors, textbooks would generally be found in the lower left quadrant:



Textbooks generally alternate verbal and graphic stimuli and require passive responses.

The textbook analysis was to provide a working basis for specifying functional requirements for a graphic teaching machine. This purpose was served to a limited extent. The stimulus categories generated by the analysis provide a least set of display capabilities for a machine and the response categories provide a least set of response capabilities. However, the full range of graphic stimulus and response interaction that is possible in the instructional process was not illuminated by the textbook analysis. With the exception of vocalizing to musical stimuli, very little active or graphic response to graphic stimuli was

required of the textbook reader.

The use of graphics in textbooks raises questions about their use in other educational media. How do graphics interact with the verbal and symbolic-numeric modes when instruction is by a tutor, a classroom teacher, or film or ETV? How do changes in graphics and their interaction with other modes effect learning? It would be reasonable to extend the content analysis developed for this study to other media. The larger taxonomic scheme would make it possible to compare the use of graphics in the different media. Further, with the stimulus, response, and S-R categories isolated, more experiments like the one reported in Part II could be conducted to evaluate the relative effects of the S-R categories on learning.

Appendix A

Stimulus-Response Combinations by Subjects

Subject	Stimulus Category	Response Category	N
Algebra:			
	1a	6	1
	1b	7	1
		8	1
		6	2
		10	2
	2a	8	2
	2b	8	4
		10	2
	3a	5	2
		6	2
		10	2
	4a	10	1
	6	6	8
		7	1
		9	8
	7a	6	2
		7	1
		12	2
	7b	6	6
		8	1
		9	1
	8a	9	2
	8b	6	7
		7	1
		8	3
		9	2

(Algebra)

9a	3	1
	6	1
	7	1
	8	13
	9	1
9b	3	3
	6	2
	7	6
	8	24
10a	6	1
	7	1
	8	10
	9	1
	11	1
10b	2	1
	7	5
	8	15
11a	1	1
	6	3
	8	4
	9	3
	15	1
11b	6	2
	8	6
	9	3
	10	1
	11	1
12	2	1
	7	2
	11	1

(Algebra)	13	3	1
		7	2
		11	8
		12	2
		16	2
	14	13	3
		14	1
	15	1	2
		2	3
		3	4
		11	19
		12	4
		13	2
		14	1
		16	2
	16	12	5
		14	2
		15	6
		16	3
	17	3	1
		11	5
		12	58
		13	10
		14	3
		16	1
	18	1	1
		2	5
		3	8
		6	1
		11	8
		12	41
		13	7
		14	3

(Algebra)				
	18 (con't)	15		1
		16		13
	19	1		1
		3		2
		11		2
		12		34
		13		11
		14		3
			Total	474
Biology:				
	2a	8		27
	2b	8		73
		9		3
		10		4
		15		2
	3a	8		123
		10		3
		15		2
	3b	8		7
	3c	8		13
	4a	8		2
		15		1
	4b	8		1
	5a	6		8
	5b	8		14
	8b	9		19
		15		1
	9a	8		1

(Biology)	11a	8		3
	11b	8		17
	12	1		1
		15		3
	13	1		1
		4		3
		8		1
		15		10
	16	1		3
		2		2
		4		1
		8		1
		15		226
			Total =	576
Music:				
	2a	5		333
		6		1
		8		8
		10		18
	3a	8		12
		10		9
	11a	8		3
	16	2		1
		15		59
			Total =	444

Appendix B

High School Textbooks Analysed

Subject	Author(s)	Title	Publisher	Date
Algebra:				
	Edgerton, et al.	Intermediate algebra	Allyn-Bacon	1957
	Lennes, et al.	Second course in algebra	Macmillan	1957
	Mallory, et al.	Second course in algebra	Singer	1961
	Mayor & Wilcox	Algebra: second course	Prentice Hall	1957
	Smith & Lankford	Algebra two	Harcourt-Brace	1955
	Welchous, et al.	Algebra, book 2	Ginn	1960
	Wells & Hart	Progressive second algebra	Heath	1943
Biology:				
	Baker, et al.	New dynamic biology	Rand-McNally	1959
	Dodge	Elements of Biology	Allyn-Bacon	1959
	Fitzpatrick & Bain	Living things	Holt-Rinehart-Winston	1958
	Moon, et al.	Modern biology	Holt-Rinehart-Winston	1960
	Smith & Lisonbee	Your biology	Harcourt-Brace	1958
Music:				
	Davison, et al.	Concord song and junior chorus book	Schirmer	1928
	Farnsworth, et al.	Singing youth	Summy-Birchard	1935
	McConathy, et al.	New music horizons	World Music	1951
	McKinney	Music and man	American	1948

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PART II

INVESTIGATIONS COMPARING SYMBOLIC AND GRAPHIC TEACHING PROGRAMS

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Warren H. Teichner
Albert E. Hickey

Introduction

Recent reviews of research on automatic teaching devices (Carr, 1959; Morrill, 1961) have pointed out a need for investigations which deal with the characteristics of the display mode. Presently used commercial devices, e.g., the Skinner teaching machine and its variants, generally confine the stimulus and correct response to a small 1 × 7 inch display area. The student's response must be made in an even smaller area. Although minor graphic displays may be shown as part of the item, major graphic and textual displays must be presented in separate supplements. This restriction of stimulus and response areas is becoming increasingly more critical as the realm of subject matter for programmed learning increases. For example, for certain subject matters, such as training for equipment operation and maintenance procedures of aspects of mathematics and the sciences, programs may be more effective with graphic or pictorial displays. Much information might also be gained through the use of pictorial displays and graphs even for those materials which are largely verbal.

The subject matter of mathematics is generally considered to be readily adaptable to the present devices since it may be written in symbolic language. Yet, even within the broad range of mathematics, there are programs for certain topics which may be presented more cryptically than others, e.g., sets, Relations and Functions (Eigen, 1961), and Probability and Statistics (Hickey and Autor, 1961). If the elimination of major pictorial displays from these programs has hindered learn-

ing, then the design characteristics of the present devices are in need of change. Thus the need for comparison of the symbolic and graphic modes of presentation encompasses all subject matter.

It was the purpose of the present experiment to explore the relative effectiveness of symbolic versus graphic modes of presentation and response. The subject matter that was used for investigation was Boolean algebra. This form of mathematics has an advantage over other materials in that it can be presented in two exactly equivalent forms. In the symbolic mode, problems and answers take the form of mathematical equations, while in the graphic mode the material is conventionally presented in the form of circuit diagrams. Further, there is a formal equivalence between the symbolic and graphic modes with respect to the numbers and operations in the system.

In an attempt to increase the generality of results beyond mathematics and Boolean algebra, the major test sections involved the translation of verbal problems of logic to their graphic or symbolic expressions, and, conversely, translations from these expressions to verbal statements. These translations are a process of encoding verbal materials into another form and of decoding the expressions back into the verbal form. Although the materials are specific to Boolean algebra, the processes of encoding and decoding can be applied generally to the relationship of verbal language to symbolic and graphic materials, e.g., the interpretation of a graph or equation requires a comparable decoding, while the construction of a graph or expression from a set of verbal statements requires a comparable encoding. Thus the use of Boolean algebra in the present experi-

ments was intended to provide an initial experimental comparison of general significance between graphic and symbolic modes and between the encoding and decoding processes.

Methodology

Apparatus. The device for providing the programmed materials was a booklet constructed as shown in Fig. A-1 (Appendix 1). The left-hand side of the pages of each booklet was stapled onto a cardboard mount, while the right-hand side was passed through, and concealed under, a slit in the cardboard. The visible portion of each page contained instructional material, while the portion concealed in the slit contained the correct answers. The subject read the exposed portion of the page, filled in his answer in the blank spaces provided in this portion, and then pulled the right side of the page out of the slit. This procedure allowed the subject to receive immediate knowledge of results. After making a comparison between the written and correct answers, the page was then folded back to the left and the next page was thus ready for the subject.

Although subjects were run in groups, each subject was permitted to proceed at his own pace. The time of starting and of completing each section was always recorded by the subject and provided a measure of individual differences in performance time.

Experiment I

A number of preliminary attempts to construct adequate programs were made and evaluated by running small numbers of volunteer subjects through them. Based on the problems revealed from scoring

these subjects and their comments about the booklets and the administrative procedures, final booklets were made for use in Experiment I. This experiment was intended to be a more formal preliminary evaluation of the procedures and materials as well as a source of preliminary information about the differences between graphic and symbolic presentation modes. In addition, this experiment was intended to provide data relevant to possible differences between high school and college subjects.

Subjects. The subjects were 16 high school seniors from Newburyport High School, Newburyport, Massachusetts and 16 freshmen from Northeastern University, Boston, Massachusetts. None of these students had any previous experience with Boolean algebra or its concepts.

Apparatus. Two programs, one in symbolic form and the other graphic, were constructed. Each program consisted of four sections of 12 frames each which were identical except for the difference in mode. The sections of the programs and their purposes are as follows:

Section A. Introduction to Boolean Algebra and Basic Definitions. For the symbolic program this section included definitions of 0 and 1 as the numbers of the system and of addition and multiplication as the operations of the system. The equivalent definitions were provided for the graphic program in terms of open and closed switches as the "numbers" and parallel and series circuits as the "operations."

Section B. Advanced introduction: Simple Problems. In this section simple problems were presented which required the use of definitions and operations previously taught. The problems consisted of

non-verbal, "if-then" statements and periodic reviews of these statements. The "if" part of each of the non-verbal statements was presented, and the subject filled in the "then" blank with a 0 or 1, or its graphic equivalent.

Section C. Advanced introduction: Complex Problems. The problems in this section were based on those of the previous section, but differed in that here the problems used actual complex symbolic equations and graphic forms which were of the type that would be encountered in Section D. Thus, this section was considered to be a transition for preparing the subject for Section D.

Section D. Complex problems and Encoding. This section, presented verbally, stated logical problems which were to be encoded into graphic or symbolic equations. This was the only section in which the subject was required to encode. Procedure: The two groups of subjects at each school level were used in a crossover experimental design in which one group learned the four sections (Sections A through D) first with the symbolic program and then with the graphic program. The other group first worked through the graphic program and then through the symbolic program. A summary of this experimental design is presented in Table I.

The maximum total time to complete all eight sectionswas two hours. No rest period was given between the sections or the programs. Results: The data were analyzed in terms of the rate of work, expressed as items accomplished per minute (regardless of accuracy) and the percentage correct. The rate measures were derived from the records of time required to complete each of the four sections of the program.

TABLE 1

A SUMMARY OF THE EXPERIMENTAL DESIGN FOR EXPERIMENT I

GROUP	SCHOOL LEVEL	FIRST PROGRAM	SECOND PROGRAM
I	High School	Symbolic	Graphic
II	High School	Graphic	Symbolic
III	College	Symbolic	Graphic
IV	College	Graphic	Symbolic

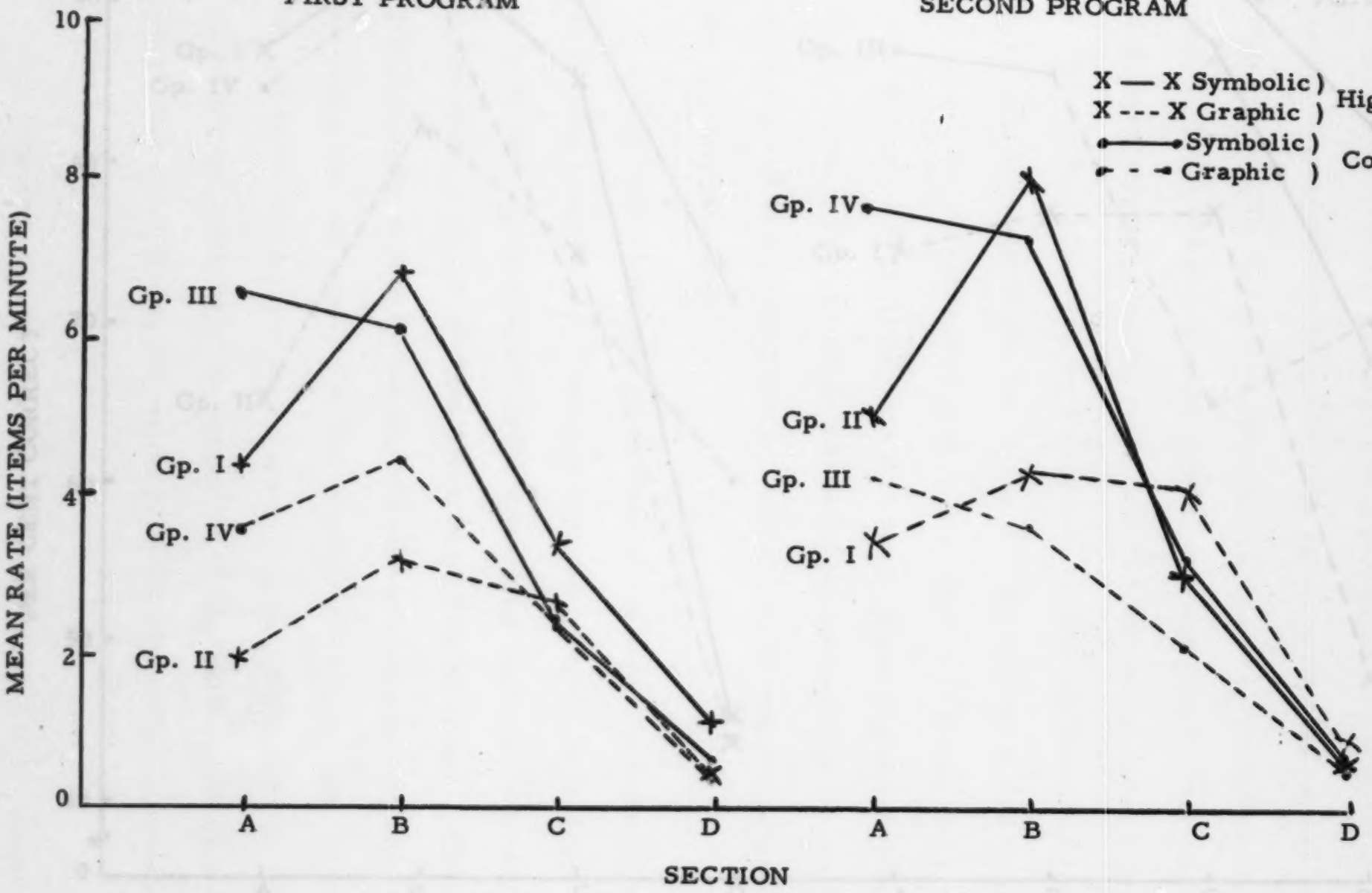


Fig. 1. Mean rate of work, by each group in Experiment I, on each program and section.

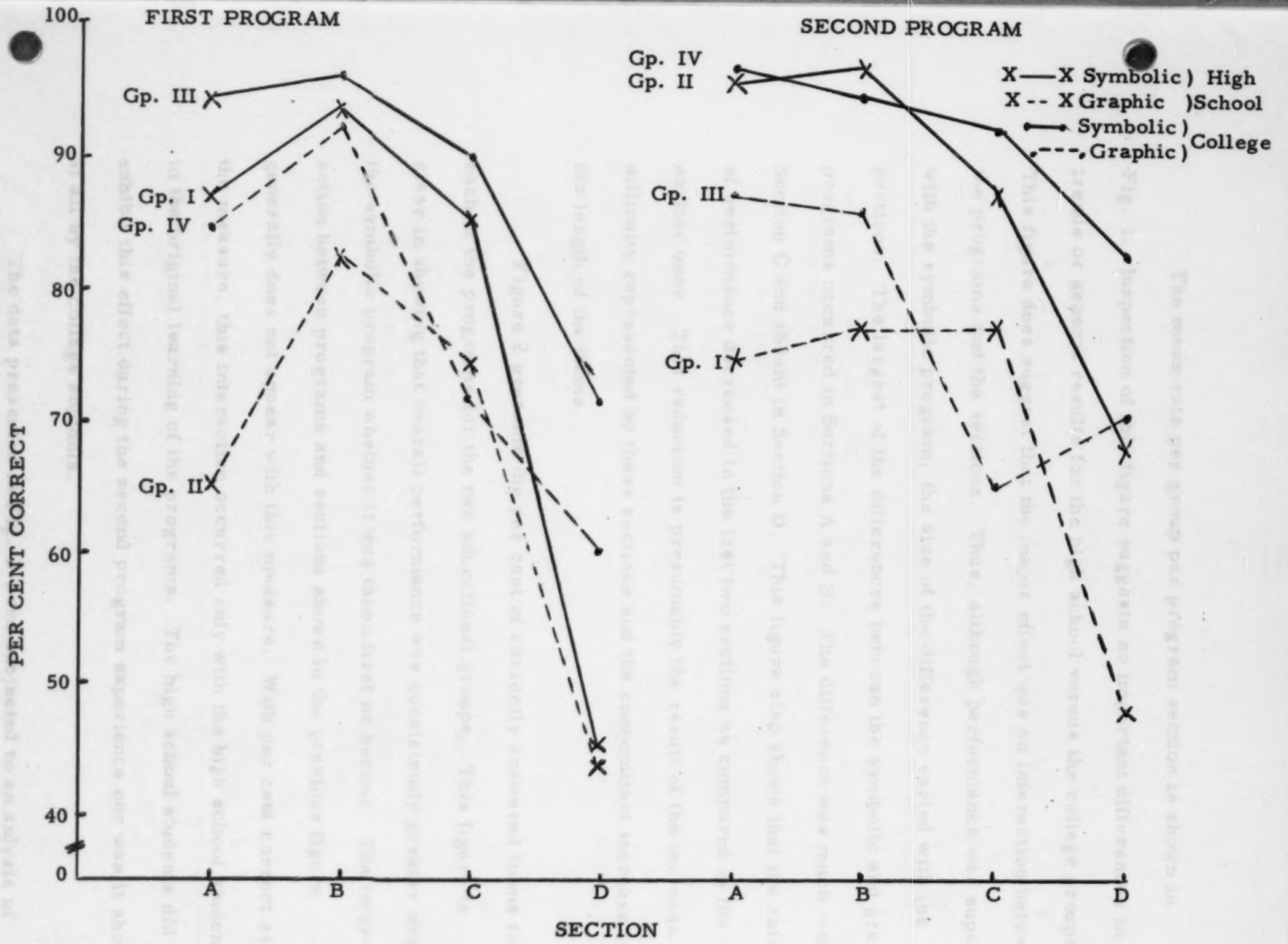


Fig. 2. Mean per cent correct responses, by each group in Experiment I, on each program and section.

The mean rate per group per program section is shown in Fig. 1. Inspection of this figure suggests no important differences in trends or general results for the high school versus the college groups. This figure does suggest that the major effect was an interaction between the programs and the sections. Thus, although performance was superior with the symbolic program, the size of the difference varied with the sections. The largest of the differences between the symbolic and graphic programs occurred in Sections A and B. The difference was much less in Section C and absent in Section D. This figure also shows that the rate of performance decreased in the last two sections as compared to the earlier ones. This reduction is presumably the result of the increase in difficulty represented by these sections and the concomitant increase in the length of the items.

Figure 2 presents the per cent of correctly answered items for each of the programs for the two educational groups. This figure is clear in showing that overall performance was consistently greater with the symbolic program whether it was taken first or second. The interaction between programs and sections shown in the previous figure generally does not appear with this measure. With per cent correct as the measure, this interaction occurred only with the high school students in the original learning of the programs. The high school students did not exhibit this effect during the second program experience nor was it shown at all by the college students.

The data presented in Fig. 2 were subjected to an anlysis of variance which is summarized in Table 2. As the table shows, both the

TABLE 2

ANALYSIS OF VARIANCE OF PERCENTAGE CORRECT FOR EXPERIMENT I

Between Ss Total	31		
School Level (A)	1	4,697.816	3.982
Sequence (R)	1	513.446	.435
A x R	1	22.952	.019
Ss/A x R	28	1,179.529	
Within Ss Total	224		
Transfer (T)	1	1,121.630	4.794*
Programs (P)	1	11,833.861	50.800**
A x T	1	284.863	1.217
A x P	1	62.717	.268
Ss x P/A x R	28	233.930	
Within Ss Within Programs			
Sections (S)	3	10,091.325	46.168**
S x A	3	1,307.660	5.982**
S x R	3	108.051	.494
S x R x A	3	111.532	.510
Ss x S/A x R	84	218.575	
S x T	3	696.188	.313
S x P	3	146.600	.066
S x A x T	3	13.452	.006
S x A x P	3	467.538	.210
Ss x S x P/A x R	84	2,226.310	

* P .05
** P .01

Programs and the Sections were significant sources of variance as was the interaction between School Levels and Sections. One surprising result of the analysis was the fact that the average differences between high school and college students shown in Fig. 2 failed to reach significance. Thus the strong suggestion that college students were more accurate in their responses must be treated with caution.

Table 2 also reveals that there was a significant difference between performances on the first and second programs, i.e., the results suggest a positive transfer effect between programs. The non-significant interaction between Transfer and Section, suggesting a general transfer effect throughout the sections, is not consistent with Fig. 2 since the figure shows that the greatest transfer effect was related to Section D. On the other hand, the failure of the interaction between Transfer and School Level to be significant is supported by the figure. Figure 2 suggests further that the transfer effect was represented by a gain in performance for those who switched from the graphic to the symbolic program and that this was the case for both high school and college students. This suggested interaction could not be tested statistically with the present experimental design.

Discussion - Experiment I

1. The discrepancy between the results with per cent correct and rate of work suggests that the rate at which people work may not be the best measure of learning. This can be seen best in terms of the results in Section D. Although there was no difference between the symbolic and graphic programs or between the high school and college

students with respect to rate of work, there were definite differences in terms of accuracy of performance. This leads to an obvious, but often overlooked, conclusion that a rate of work or time measure is useful only when a pure speed test is used. In the case of power tests where the material is difficult and errors occur, rate of work does not necessarily reflect the accuracy that might be attained with unlimited time.

2. Although there was greater accuracy with the symbolic program, this did not necessarily mean that the symbolic method of presentation is superior to the graphic method. Since the differences between programs were consistent for all sections, including the first, the results can be interpreted to indicate that the introductory sections did not give adequate training for the graphic test material. The difference in performance on Section D has little value as a test of the differences between symbolic and graphic training since the groups were not comparable or equated when they began this section. In order to get a valid measure of the differences in learning with the two methods of presentation, the groups must obtain equal benefit from the introductions.

3. The differences between the programs on Sections A, B, and C may be attributed to the differences in familiarity with the language that was used. All students of high school and college age are familiar with the numbers 0 and 1 and with the operations of multiplication and addition, but relatively few, if any, are familiar with the corresponding graphic numbers and operations. This leads to the suggestion that subjects learning the graphic programs did not have as adequate an understanding of the language that was used as those learning the symbolic programs. Thus, the graphic learners

could be thought of as being unfairly handicapped in Section D which involved a coding of verbal material into the graphic language.

Experiments II and III

Based on the findings of Experiment I, a decision was made to develop new introductory sections which concentrated solely on the forms of the pictures and equations that were to be encountered in the text sections. Two 12 frame sequences were developed, one graphic and one symbolic. Preliminary research during this development was used to insure that these introductions could be learned with a minimum accuracy of 90%. This criterion of 90% accuracy was used to establish a high and comparable level of performance for both the symbolic and graphic groups prior to their learning of the test sections.

The test section was expanded to 17 frames per sequence and another set of 17 frame test programs was developed to take into account those situations which require the translation of the picture or equation into a verbal statement. Samples of the programs are presented in Appendix B. These materials were used for further investigation, the purpose of which was (1) to continue exploration of the effectiveness of the graphic and symbolic methods of presentation, (2) to investigate the encoding and decoding processes, and (3) to obtain more data concerning the different transfer effects.

Method: Ideally, the questions of interest could have been investigated using a complex crossover design in which all the subjects would have experienced all the sections of both the symbolic and graphic programs. To achieve this within the existing limitations of time and cost was not feasible. Instead, two smaller experiments were conducted each of which

was intended to supply a portion of the total desired information. These experiments, Experiments II and III, will be presented simultaneously.

Subjects: One hundred forty-four students enrolled in four elementary psychology classes at Northeastern University were used for the experiments. Sixty-eight of these students served in Experiment II while the remaining seventy-six served in Experiment III. None of these students had any previous experience with Boolean algebra.

Apparatus: The sections of the programs and their purposes are as follows:

Section A. Introduction and Basic Definitions. This section consisted of statements and problems emphasizing the encoding and decoding of addition and multiplication in actual symbolic equations or parallel and series in actual graphic pictures.

Section B. Decoding Test Section. This section was composed of problems involving the translations of symbolic or graphic expressions into verbal statements.

Section C. Encoding Test Section. The problems in this section involved the translation of verbal statements into symbolic or graphic expressions.

Procedure: Tables 3 and 4 present the crossover experimental designs for Experiments II and III respectively. In Experiment II, one group of subjects learned only the graphic program, while the other worked only on the symbolic program. Within the graphic and symbolic groups, half of the subjects first learned Section B (decoded) and then performed on Section C (encoded), while the other half did the reverse. In Experiment III, one group

of subjects learned only Section B (decoded), while a second group worked only on Section C (encoded). Within each of these two groups, half of the subjects first learned the graphic and then switched to the symbolic program, while the other half did the opposite.

An inspection of Tables 3 and 4 shows that the two experiments differ only after the groups switch to different programs. Thus, Experiment III is a replicate of Experiment II when consideration is given only to the programs that were experienced initially.

Results of Experiment II.

Since Section A was developed with the aim of obtaining high and comparable symbolic and graphic performance, little difference would be expected between these groups on this section. The actual per cent correct with the symbolic program was 93.37% and with the graphic 90.44%. This difference as evaluated by the student's t test was not significant. This finding, it will be recalled, is a necessary prerequisite for evaluating the graphic versus symbolic modes in the later section.

Figure 3 presents per cents correct for the various groups for Sections B and C. Inspection of this figure reveals that the graphic groups performed with greater accuracy than their respective symbolic groups. It can further be seen that the performances with Section B, the decoding section, was superior to the performances with Section C, the encoding section. Figure 3 also suggests that there was positive transfer when switching from the first to the second program, i.e., performance was superior on the program that was experienced second.

TABLE 3

A SUMMARY OF THE EXPERIMENTAL DESIGN FOR EXPERIMENT II

GROUP	MODE	FIRST PROGRAM	SECOND PROGRAM
I	Symbolic	Section B (decoding) - equation to verbal	Section C (encoding) - verbal to equation
II	Symbolic	Section C (encoding) - verbal to equation	Section B (decoding) - equation to verbal
III	Graphic	Section B (decoding) - picture to verbal	Section C (encoding) - verbal to picture
IV	Graphic	Section C (encoding) - verbal to picture	Section B (decoding) - picture to verbal

TABLE 4

A SUMMARY OF THE EXPERIMENTAL DESIGN FOR EXPERIMENT III

GROUP	SECTION	FIRST PROGRAM	SECOND PROGRAM
I	Section B (decoding)	Symbolic	Graphic
II	Section B (decoding)	Graphic	Symbolic
III	Section C (encoding)	Symbolic	Graphic
IV	Section C (encoding)	Graphic	Symbolic

An analysis of variance of the data in Fig. 3 is summarized in Table 5. The major trends that were observed in Fig. 3 were confirmed by the fact that the main effects of Program Modes, Sections, and Transfer were all significant sources of variance. The failure of the interaction between Transfer and Programs suggests that there is no difference in gain for a symbolic to symbolic program experience as compared to a graphic to graphic one.

Although a statistical test of the interaction between Transfer and Section within Programs was not permissible, Fig. 3 does not suggest any consistent relationship. The fact that there was greater transfer when encoding (Section C) followed decoding (Section B) can be attributed solely to the subjects who learned the symbolic programs, i.e., a 13.13% increase in symbolic C when it followed B, and a 1.17% increase in symbolic B when it followed C. For the graphic groups the differences in transfer were slight, and in the opposite direction.

Figure 4 presents the results obtained with the rate of performance measure. Inspection of this figure by itself seems to have little importance in view of the limitations about rate which were noted above in the discussion of Experiment I. A comparison of Fig. 4 with Fig. 3 suggests an interesting inverse relationship between accuracy and rate. This is suggested especially by the results of the symbolic C and graphic B conditions. The symbolic C conditions had the highest rate and the poorest accuracy, while the graphic B conditions resulted in slow rates and high accuracy.

TABLE 5

ANALYSIS OF VARIANCE OF PERCENTAGE CORRECT FOR EXPERIMENT II

SOURCE	df	MS	F
Between Ss total	67		
Programs (P)	1	3,399.700	5.299 *
Sequences (R)	1	188.259	.293
P x R	1	471.809	.735
Ss/P x R	64	641.597	
Within Ss total	68		
Sections (S)	1	4,247.618	25.778 **
Transfer (T)	1	1,601.330	9.718 **
P x T	1	5.238	.032
P x S	1	.000	.000
Ss x S/P x R	64	164.775	

* P .05
** P .01

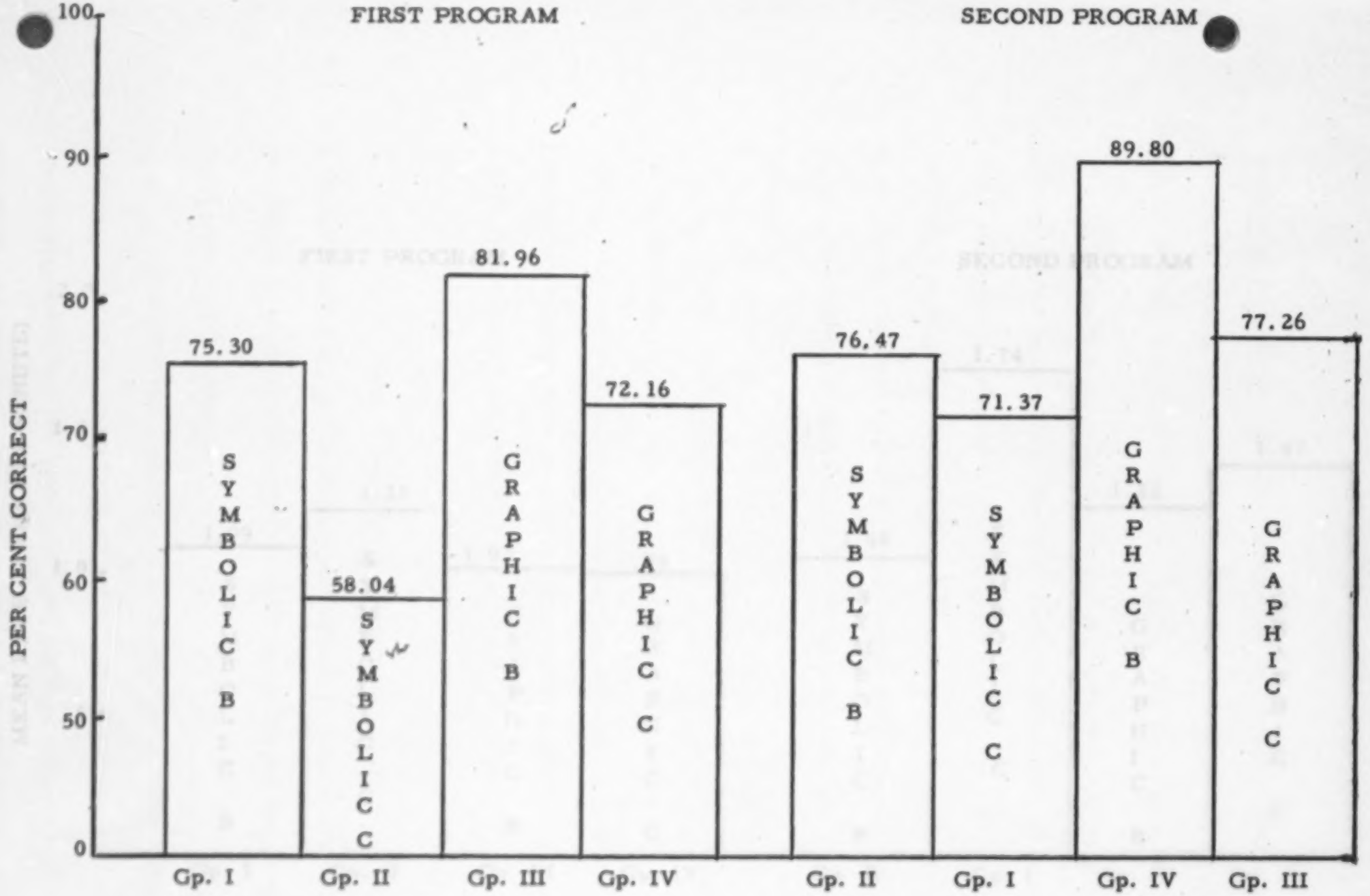


Fig. 3. Mean per cent correct responses in Experiment II for each group on each program and section.

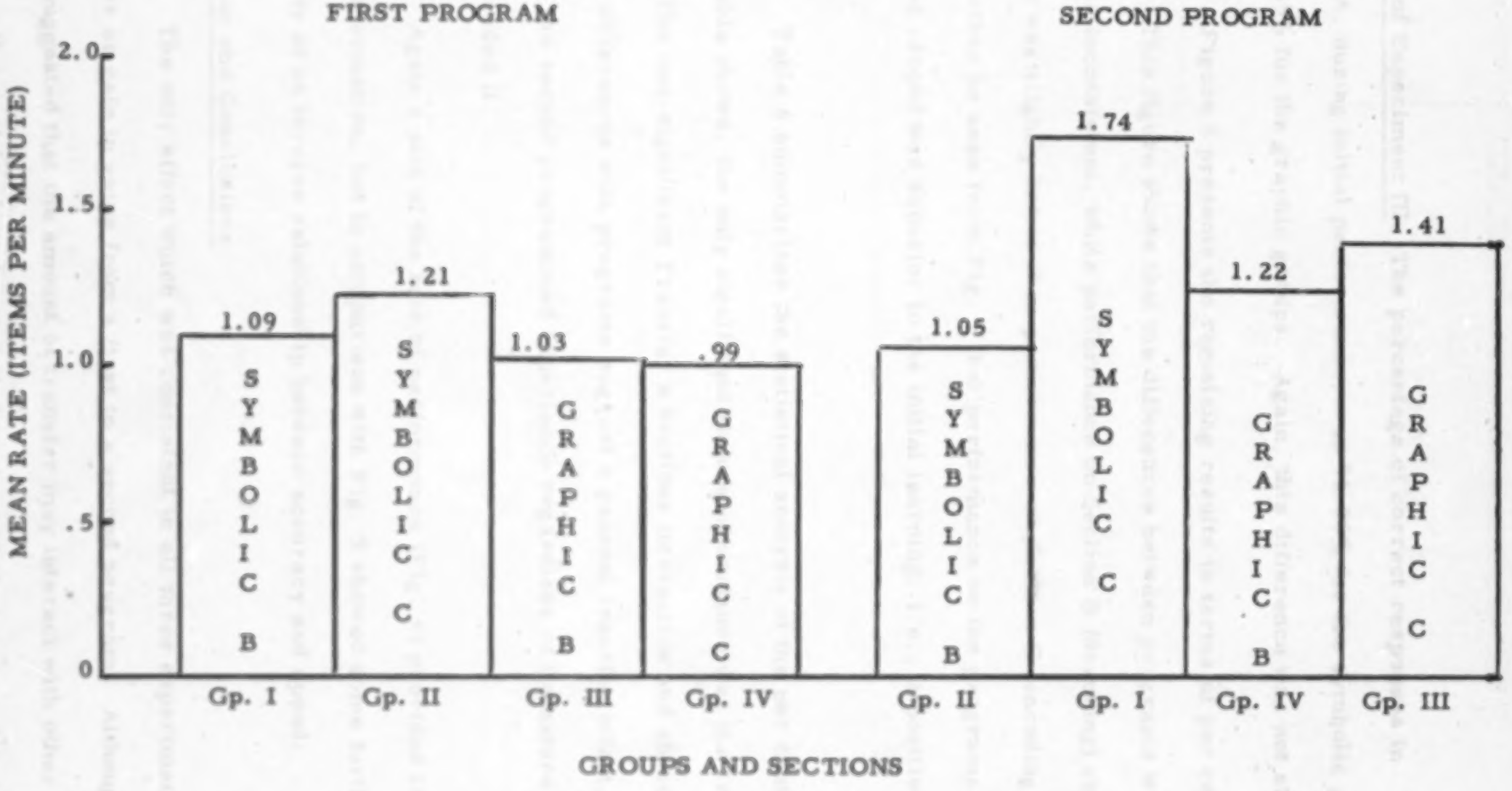


Fig. 4. Mean rate of work in Experiment II for each group on each program and section.

Results of Experiment III: The percentage of correct responses in Section A, during initial performance, was 94.08% for the symbolic groups and 91.45% for the graphic groups. Again, this difference was not significant.

Figure 5 presents the remaining results in terms of per cent correct. This figure shows that the differences between programs were small and inconsistent, while performance on Section B (decoding) consistently was slightly better than performance on Section C (encoding). It can further be seen from Fig. 5 that performance on the programs experienced second was superior to the initial learning, i.e., a positive transfer.

Table 6 summarizes the statistical analysis of the per cent data. As the table shows, the only significant source of variance was the transfer effect. The non-significant Transfer x Sections interaction and absence of transfer differences with programs suggest a general transfer effect, i.e., a gain in the second programmed experience regardless of its nature or of what preceded it.

Again a plot of the rate of performance (Fig. 6) provided little further information, but in comparison with Fig. 5 showed some further possibility of an inverse relationship between accuracy and speed.

Discussion and Conclusions

The only effect which was consistent in all three experiments was a transfer or gain in going from a first to a second program. Although the results suggested that the amount of transfer may interact with other variables, the statistical analyses failed to support these suggestions.

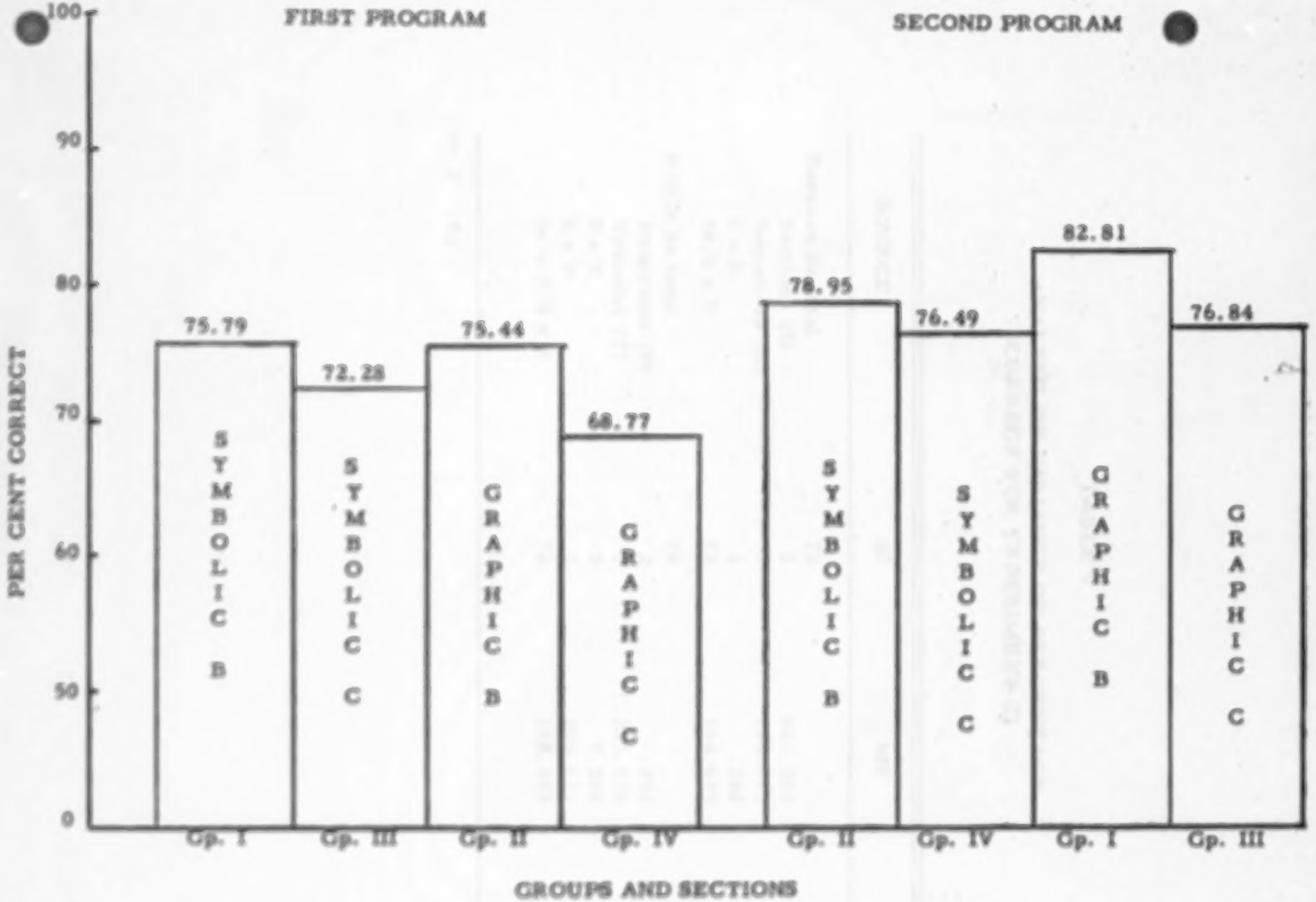


Fig. 5. Mean per cent correct responses on each program and section for each group in Experiment III.

TABLE 6

ANALYSIS OF VARIANCE OF PERCENTAGE CORRECT FOR EXPERIMENT III

SOURCE	df	MS	F
Between Ss total	75		
Sections (S)	1	821.283	1.627
Sequences (R)	1	154.611	.306
S x R	1	.288	.001
Ss/S x R	72	504.699	
Within Ss total	76		
Programs (P)	1	.292	.002
Transfer (T)	1	1,235.076	7.812**
S x T	1	7.269	.046
S x P	1	105.611	.668
Ss x P/S x R	72	158.103	

** p .01

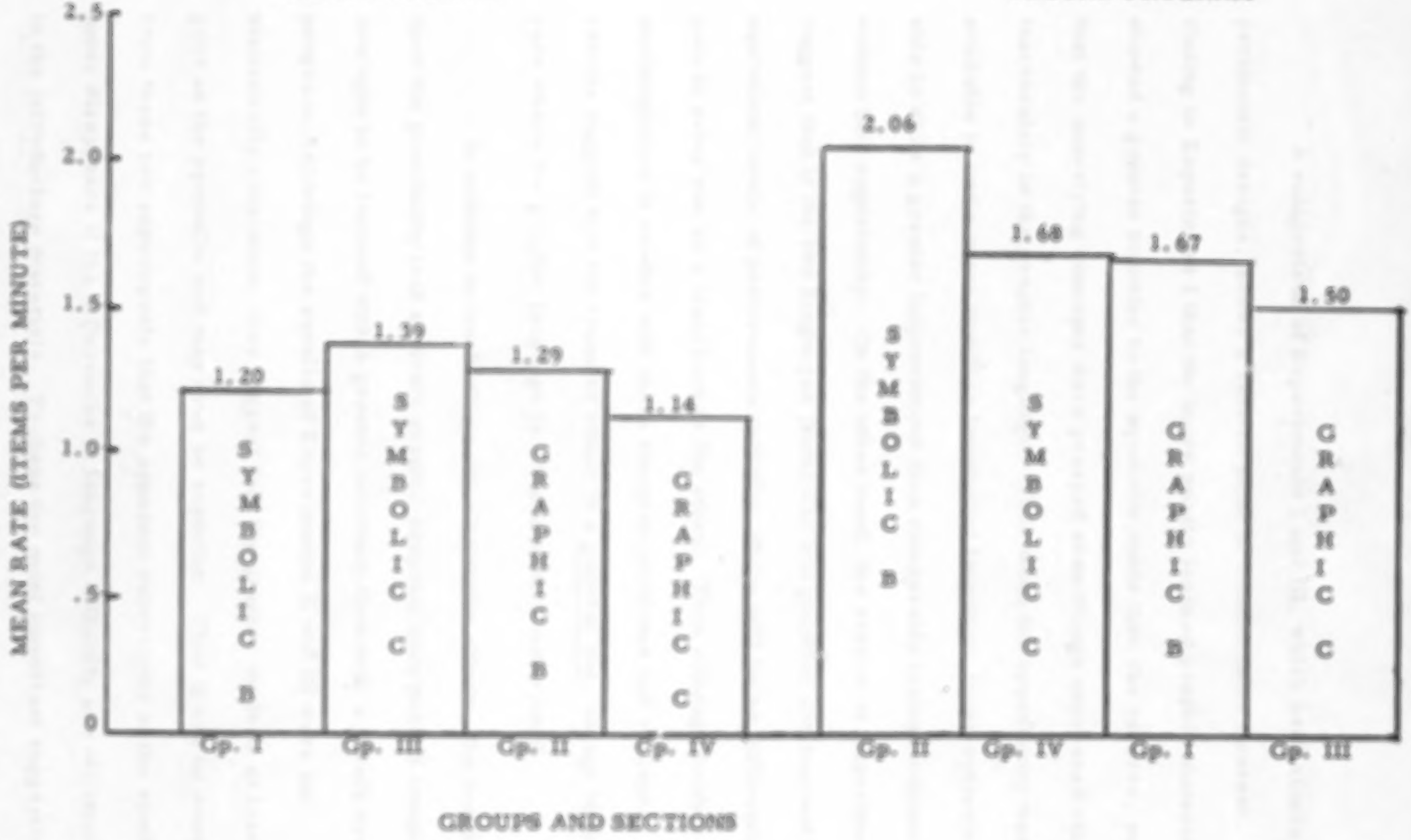


Fig. 6 Mean rate of work on each program and section for each group in Experiment III.

A comparison of Experiments I and III, which used similar experimental designs, shows a related point of considerable interest. The finding in Experiment I that the more poorly learned graphic material showed a greater transfer to the symbolic mode than the reverse, suggests that the underlying concepts were grasped even though expressed relatively inaccurately in the graphic language. Thus when the opportunity was available to use a more familiar (symbolic) language, these subjects were able to show a greater improvement than comparably trained subjects without this opportunity. On the other hand, the results of Experiment III suggest that if the two languages (symbolic and graphic) are learned to equivalent levels of performance initially, there will be no differential gain in using one as a transition to the other. Thus although further experimentation is needed with more complex problems and concepts, the results suggest that the transfer effect is a general one, except in the case where the graphic language is not adequately understood.

In addition to the findings about transfer effects, the results open the possibility that a purely graphic program may permit complex concepts to be learned with a greater accuracy than with a purely symbolic program. Although the results of Experiments II and III were not statistically consistent, they suggest that the graphic mode is at least as good as the symbolic and may even be superior. Thus it can be seen from these two experiments that the apparent superiority of the symbolic mode disappears if the differences in language difficulty are eliminated in the introductory materials. Perhaps the most important suggestion in this regard then is the necessity of learning the graphic language for

its use in teaching concepts or for problem solving. More simply, the better a tool is mastered, the greater becomes its utility.

In both Experiments II and III, decoding performance was found to be superior to encoding performance, although this was not supported statistically in Experiment III. This lack of statistical confirmation may not be too critical in this instance since performance was in the same direction in both experiments and since the finding was relatively marked, consistent, and significant in Experiment II. This suggests that the best performance may be obtained when subjects are presented with a graphic picture or symbolic equation and then required to translate it into its verbal meaning. Further research which explored the difference between encoding and decoding would appear to be warranted and possibly very fruitful.

Further exploration is also needed to establish the relationship to the rate and accuracy measures. All three experiments show that the rate at which people perform may not be a good indicator of the amount of learning, while Experiments II and III further suggest that the conditions in which subjects work more slowly and carefully may also be the ones which produce the greatest learning.

One final finding of considerable interest was the failure of the results for the first program of Experiment III to be a replication of the corresponding results in Experiment II. Inspection of Fig. 3 and 5 reveals that the major discrepancy occurred with the symbolic groups on Section C. No ready explanation can be offered for differences in results, although a number of obvious sources of variance can be considered, e.g., sampling

biases due to when the experiments were run, and possible differences in background. These and other factors must be given more careful consideration in future experiments.

In general, the results of the three experiments were disappointing in leading to strong conclusions. On the other hand, in view of the exploratory nature of the experiments, much has been gained for the development of methodology for future studies. In particular, the inconsistency among experiments suggest a need for more reliable administration procedures. In addition to the selection of more homogeneous subject groups, there might be a gain in providing subjects with replications of the experiment using equivalent but different forms. This procedure should be supplemented by examinations which are independent of the learning program itself, i.e., the criterion for amount of learning should not be confounded by the actual learning experience. The addition of these procedures points out the further need for experiments which are carried out for an extended duration. Thus future experiments should provide subjects with a variety of concepts to be learned and should present these materials over a period of days or weeks. The criterion tests should be given at the end of each topic and then administered in alternate forms periodically to test for retention of the concepts.

Finally, a recommendation can be made to continue explorations comparing the symbolic and graphic modes, and the encoding and decoding processes. These investigations should utilize a variety of topics, which are extracted from the different types of available subject matters, in

order to study the various interactions which may occur between the subject matters and the modes or processes. In addition to the purely symbolic and purely graphic programs, benefits may also be obtained through the use of programs which combine the qualities of both presentation modes.

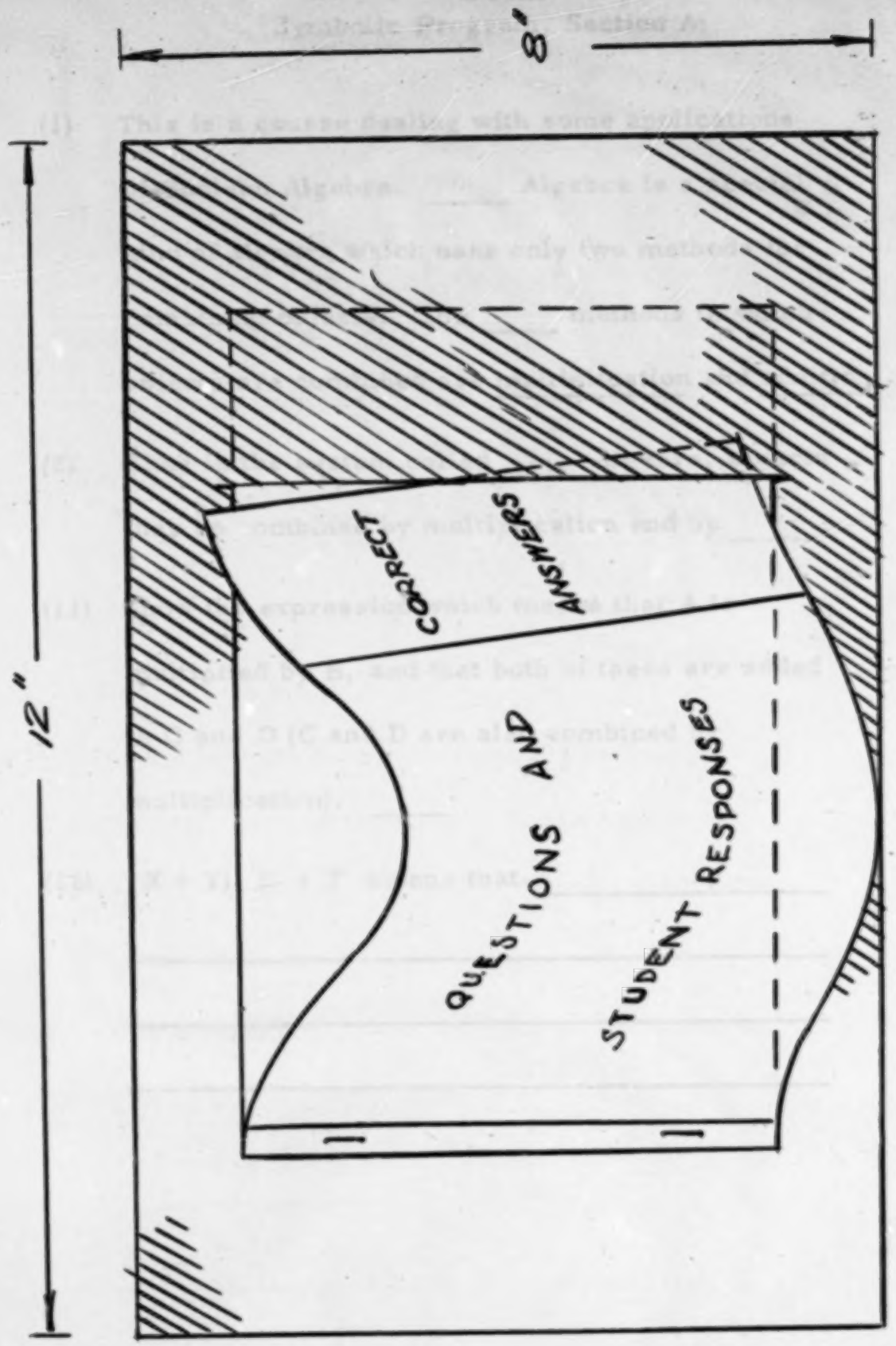


Fig. A-1. A diagram showing the construction of the test booklet and mount.

Appendix B

Sample Statements, Questions, and Correct Answers From Symbolic Program, Section A:

(1) This is a course dealing with some applications of Boolean Algebra. _____ Algebra is a special kind of algebra which uses only two methods for combining objects. The _____ methods in which two objects are combined are multiplication and addition.

Boolean

two

(2) Thus in the system called _____ Algebra, objects may be combined by multiplication and by _____.

Boolean

addition

(11) Show the expression which means that A is multiplied by B, and that both of these are added to C and D (C and D are also combined by multiplication). _____

(A B) + (C D)

(12) X + Y) Z + T means that _____

_____

_____

_____.

X is added to Y and both are multiplied by Z and all of these together are added to T

Sample Statements, Questions and Correct Answers
From
Graphic Program, Section A

(1) This is a course dealing with some applications of Boolean Algebra. _____ Algebra is a special kind of algebra which uses only two methods for combining objects. The _____ methods in which objects are combined are called series and parallel.

Boolean

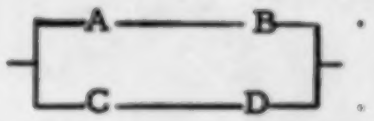
two

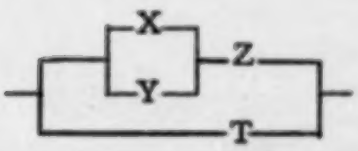
(2) Thus in the system called _____ Algebra objects may be combined in series and in _____.

Boolean

parallel

(11) Show the expression which means that A is in series with B, and that both of these are in parallel with C and D (C and D are also combined in series).



(12) 

means that _____

X is in parallel with Y and both are in series with Z and all of these together are in parallel with T.

Sample Statements, Questions, and Correct Answers
From
Symbolic Program, Section B:

(1) Bob wants to go to the movies. The people with whom he will go are illustrated by the following expression:

$J + M$

Where:
J = John
M = Mary

This expression means that Bob will go with "either John or Mary."

Jack wants to sing. The people with whom he will sing are illustrated by the following expression:

$L + B$

Where:
L = Larry
B = Betty

This expression means that Jack will sing with _____.

will sing with either Larry or Betty

(8) Bob has a date with Mary on next Saturday night. The places they can go are illustrated by the following expression:

$D\ (S + M)$

Where:
D = dinner
S = show
M = movie

This expression means that they can go _____

_____

_____

_____.

to dinner, and either to a show, or a movie

(9) Mrs. Jones wants to redecorate her house. The rooms that she will decorate are illustrated by the following expression:

(L + B) + (D K)

Where:
L = living room
B = bedroom
D = dining room
K = kitchen

This expression means that she will decorate _____ either the living room or the bedroom, or the dining room and the kitchen

(13) Betty has five tests next week. Betty's study schedule is illustrated by the following expression:

M (H + E) (P+S)

Where:
M = mathematics
H = history
E = English
P = psychology
S = sociology

This expression means that she will study _____ mathematics, and either history or English, and either psychology or sociology.

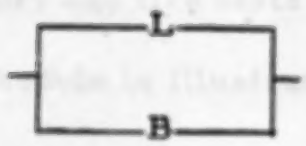
Sample Statements, Questions, and Correct Answers
From
Graphic Program, Section B

(1) **Bob wants to go to the movies. The people with whom he will go are illustrated by the following expression:**

Where:
J - John
M - Mary

This expression means that Bob will go with "either John or Mary."

Jack wants to sing. The people with whom he will sing are illustrated by the following expression:



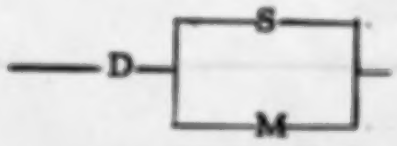
Where:
L - Larry
B - Betty

This expression means that Jack will sing with

_____.

will sing with either Larry or Betty

(8) **Bob has a date with Mary on next Saturday night. The places they can go are illustrated by the following expression:**



Where:
D - dinner
S - show
M - movies

This expression means that they can go _____

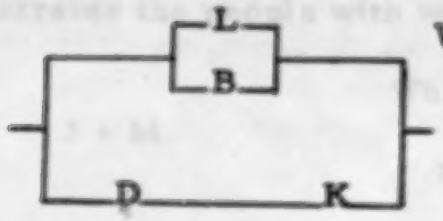
_____

_____.

to dinner, and either to a show or a movie

(9) Mrs. Jones wants to redecorate her house.

The rooms that she will decorate are illustrated by the following expression:



Where:
L = living room
B = bedroom
D = dining room
K = kitchen

This expression means that she will decorate:

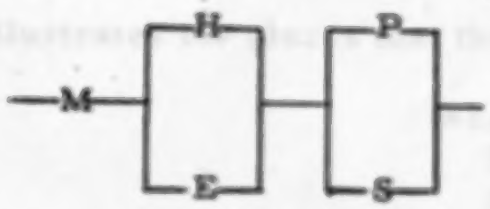
_____

_____

_____.

decorate either the living room or the bedroom, or the dining room and the kitchen.

(13) Betty has five tests next week. Betty's study schedule is illustrated by the following expression:



Where:
M = mathematics
H = history
E = English
P = psychology
S = sociology

This expression means that she will study: _____

_____

_____

_____.

mathematics, and either history or English, and either psychology or sociology

Sample Statements, Questions, and Correct Answers
From
Symbolic Program, Section C

(1) Bob wants to go to the movies. He will go with "either John or Mary." The expression which illustrates the people with whom he will go is:

J + M

Where:
J = John
M = Mary

Jack wants to sing. He will sing with either "Larry or Betty." Show the expression which illustrates the people with whom he will sing:

Where:
L = Larry
B = Betty

L + B

(8) Bob has a date with Mary on next Saturday night. They can go to dinner, and either to a show or the movies. Show the expression which illustrates the places that they can go:

Where:
D = dinner
S = show
M = movie

D (S + M)

(9) Mrs. Jones wants to redecorate her house. She will decorate either the living room or the bedroom, or the dining room and the kitchen. Show the expression which illustrates the rooms that she will decorate:

Where:
L = living room
B = bedroom
D = dining room
K = kitchen

(L + B) + (D K)

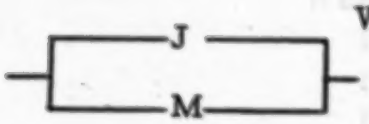
(13) Betty has five tests next week. She will study mathematics, and either history or English, and either psychology or sociology. Show the expression which illustrates Betty's study schedule:

Where:
M = mathematics
H = history
E = English
P = psychology
S = sociology

M (H+E) (P+S)

Sample Statements, Questions, and Correct Answers From Graphic Program, Section C

(1) Bob wants to go to the movies. He will go with either "John or Mary." The expression which illustrates the people with whom he will go is:



Where:
J - John
M - Mary

Jack wants to sing. He will sing with either Larry or Betty. Show the expression which illustrates the people with whom he will sing:

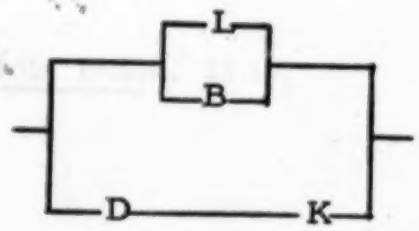
Where:
L - Larry
B - Betty

(8) Bob has a date with Mary on next Saturday night. They can go to dinner, and either to a show or the movies. Show the expression which illustrates the place that they can go:

Where:
D - dinner
S - show
M - movies

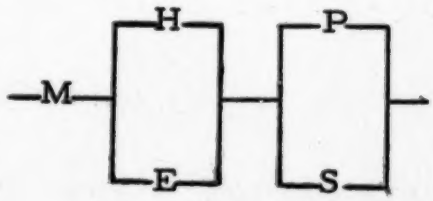
(9) Mrs. Jones wants to redecorate her house. She will decorate either the living room or the bedroom, or the dining room and the kitchen. Show the expression which illustrates the rooms that she will decorate:

Where:
L - living room
B - bedroom
D - dining room
K - kitchen



(13) Betty has five tests next week. She will study mathematics, and either history or English, and either psychology or sociology. Show the expression which illustrates Betty's study schedule:

Where:
M - mathematics
H - history
E - English
P - psychology
S - sociology



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Hickey, A. E. & Autor, S. M. Probability and statistics: a television workbook. Boston: Northeastern University Automated Teaching Project, 1961.

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Summary and Conclusions

The findings for a two-part study of the requirements for graphic teaching machines are reported. Part I describes a content analysis of the graphics used in a common educational medium: the high school textbook. Part II reports a series of experiments comparing the effectiveness of graphic and symbolic modes for learning Boolean algebra with programmed instruction.

In Part I a method for analyzing the graphic content of textbooks is described which can be extended to other educational media. The result of applying the method in this study was a reliable taxonomy of graphic stimuli, responses, and S-R combinations for textbooks. On the basis of a 480-cell taxonomic matrix it was concluded that graphics in textbooks are used primarily to:

1. Supplement already complete verbal or symbolic presentations;
2. Increase motivation, i.e., interest and attention.

The experiments in Part II used two classes of formally equivalent programmed instruction sequences, graphic and symbolic, to teach concepts of Boolean algebra. The learning achieved with the graphic programs, Graphic S→Verbal R and Verbal S→Graphic R, was compared with that achieved with the symbolic programs, Symbolic S→Verbal R and Verbal S→Symbolic R. Interactions among program classes were also evaluated. It was concluded that:

1. Positive transfer always occurred from one programmed sequence to another without respect to S or R mode.

2. Positive transfer from graphic to symbolic programs was greater than for all other orders of programs.

3. Performance was superior when translating from either graphic or symbolic presentations to verbal response as opposed to translating from verbal presentations to graphic or symbolic response.

4. Learning was as great, or greater, with graphic programs as it was with symbolic programs when experience with the two modes was equated.

A separate appendix reviews the optical and mechanical requirements for graphic teaching machines.